S/X-Band Experiment: Zero Delay Device

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A zero delay device currently being developed for the S/X band experiment is described. Preliminary group delay and transmission coefficient phase data are presented for some of the components in the zero delay device.

I. Introduction

The S/X band experiment to be performed with the Mariner Venus-Mercury 1973 spacecraft is a dual-frequency experiment to measure the electron content of the interplanetary media between Earth and the planets Venus and Mercury (Ref. 1). An uplink signal of approximately 2113 MHz will be transmitted to the spacecraft from the 64-m diam antenna at DSS 14. This uplink signal as received by the spacecraft radio system will be coherently multiplied by ratios of 240/221 and 880/221 to produce S- and X-band carrier frequencies of approximately 2295 and 8415 MHz. The coherent S- and X-band signals will then be transmitted back to the DSS 14 ground system. A measurement of the dispersiveness of the S- and X-band phase and range (or group delay) data as received back at the ground station provides scientific information required for determining total interplanetary electron content.

To calibrate group delay which is due only to the ground antenna system, a zero delay device (ZDD) is used. This device is physically installed on the ground antenna and permits group delay of the ground system to be calibrated as a function of antenna pointing direction and ambient temperatures. This article describes the ZDD which is currently being developed for the S/X experiment. Preliminary group delay and phase data on some ZDD components are also presented.

II. Description of the S/X ZDD

Figure 1 shows a simplified block diagram of the ZDD calibration system. The ZDD assembly will be installed in a low profile position on the side of the Mod-III section of the 64-m diam antenna at DSS 14. A reference 2113-MHz carrier with range-code modulation from the Mu-2 ranging machine and Block IV exciter assembly is fed into a 400-kW klystron amplifier. The amplified 2113-MHz signal is transmitted through the S-band megawatt transmit (SMT) cone microwave system and then radiated out of the SMT cone horn. A small fraction of the signal reflected from the subreflector is received by the ZDD

S-band horn. This received 2113-MHz signal is mixed with coherent 182 and 6302 MHz local oscillator frequencies provided by the Block IV exciter. As a result of mixing, down-link test signals of approximately 2295 and 8415 MHz are generated and radiated out of the ZDD S- and X-band horns back toward the subreflector. These down-link signals are received by the X-band (multiple-frequency X- and K-band (MXK) cone) and S-band (SMT cone) microwave systems. The microwave systems are followed by Block IV receivers and a Mu-2 ranging system which extract the desired S/X range information.

In essence, the function of the ZDD is to simulate a stationary spacecraft which is located on the ground antenna itself. For the S/X experiment, the ZDD will purposely be installed on the side of the Mod-III section. This location permits transmission line lengths between the ZDD and Block IV exciter to be kept physically short, and therefore, help minimize possible temperature effects on differential S/X phase and group delays.

Figure 2 is a preliminary detailed block diagram of the ZDD assembly. The ZDD assembly includes such components as S- and X-band horns, remotely controllable switches and step attenuators, mixers, and a band-pass filter. In order to have a reliable ZDD system, it is necessary that the individual components be electrically stable with regard to carrier phase and group delay. Some of the ZDD components were tested for group delay and phase stability as functions of ambient temperatures. The results are summarized in the following.

III. Test Results

A Hewlett-Packard Model 8542A automatic network analyzer was used to measure group delays and transmission coefficient phase. As described in Ref. 2, group delay can be determined from the slope of the transmission coefficient phase versus frequency characteristic curve. The advantages of using this network analyzer system are: (1) rapid and inexpensive data taking and (2) good accuracies achieved because calibration corrections are automatically applied by a computer. The tests were performed by the Western Automatic Test Service (WATS) of Palo Alto, California.

Figure 3 shows a remotely controllable step attenuator manufactured by Weinschel Engineering of Gaithersburg, Maryland. The attenuation of this device can be changed in 1-dB increments over a total dynamic range of 69 dB. Test data at pertinent S/X frequencies are summarized in Table 1. The group delay results shown are typical of data obtained over an S-band frequency range of 2000 to 2500 MHz and an X-band frequency range of 8000 to 9000 MHz. Significant test results of this device can be summarized as follows:

(1) The group delay is essentially the same at S- and X-band frequencies. In addition, the group delay is independent of attenuation setting.

(2) The transmission coefficient phase is somewhat dependent upon attenuation setting.

(3) Based on three sets of measurements in the attenuation range of 0 to 40 dB, the measured group delay values repeated to within 0.01 ns. Measured phase values repeated to within 0.1 and 0.3 deg at S- and X-band frequencies, respectively.

Figure 4 shows a remotely controllable broadband coaxial switch manufactured by Hewlett-Packard Company at Palo Alto. Test data at pertinent S/X frequencies are presented in Table 2. The group delay test results shown are typical of those obtained over the S-band frequency range of 2000 to 2500 MHz and those obtained over the X-band frequency range of 8000 to 9000 MHz. Based on the test results, it was found that for this device: (1) the group delay was essentially the same at both S- and X-band frequencies, (2) the group delay and phase values vary only slightly over the ambient temperature range of 4.4°C (40°F) to 37.8°C (100°F), and (3) based on three sets of measurements, the group delay nominal values of Table 2 repeated to within 0.01 ns and phase values typically to within 0.2 deg.

Figure 5 shows a 2113-MHz coaxial bandpass filter manufactured by Telonic Industries of Laguna Beach, California. This filter has a 3-dB bandwidth of 400 MHz. Its purpose is to filter out possible harmonic products that could be generated by the X-band mixer and reradiated out the ZDD S-band horn. Table 3 shows the test results over the filter passband. Properties of this filter can be summarized as follows: (1) the group delay varies about 1 ns in the 400-MHz passband and (2) group delay and phase data variations with temperature are small over the ambient temperature range of 4.4°C (40°F) to 37.8°C (100°F). It is also of interest to note that the group delay of 2 ns for the filter in the passband is about 7.5 times greater than the group delay of an air-dielectric coaxial line having the same physical length (8 cm) as the filter.

IV. Conclusions

Preliminary group and phase delay data have been presented for some components being installed in the ZDD assembly. It was found that for broadband coaxial devices such as the step attenuator and coaxial switches, the group delays were essentially the same at both S- and X-band frequencies. Variations of group delay and phase with ambient temperatures were negligibly small over the temperature ranges of 4.4°C (40°F) to 37.8°C (100°F).

References

1. Levy, G., Dickinson, R., and Stelzried, C., "RF Techniques Research: S/X Band Experiment," in *Supporting Research and Advanced Development*, Space Programs Summary 37-61, Vol. III, pp. 93–95, Jet Propulsion Laboratory, Pasadena, Calif., Feb. 20, 1970.
2. Adams, S. F., *Microwave Theory and Applications*, pp. 428–429, Prentice-Hall, Inc., Englewood Cliffs, N.J., 1969.

Table 1. Test data for Weinschel Model AE 97-69-3 step attenuator

Attenuator setting, dB	Group delay, ns			Estimated error limits, ns	Transmission coefficient phase, deg			Estimated error limits,[a] deg
	2110 MHz	2300 MHz	8420 MHz		2110 MHz	2300 MHz	8420 MHz	
0	0.93	0.95	0.93	±0.12	4.9	−59.7	30.0	±0.4
1	0.95	0.97	0.95		−2.6	−68.0	−0.4	
2	0.94	0.96	0.95		−0.7	−65.6	7.3	
3	0.94	0.96	0.96		−1.0	−66.1	5.7	
4	0.94	0.96	0.94		−0.7	−65.6	7.0	
5	0.93	0.96	0.96		−0.6	−65.6	7.6	
6	0.94	0.98	0.96		−0.2	−65.0	9.2	
7	0.94	0.96	0.95		0.4	−64.2	10.0	
8	0.93	0.97	0.96		1.5	−63.2	14.3	
9	0.94	0.97	0.95		0.2	−64.5	11.2	
10	0.96	0.98	0.96	±0.13	−14.3	−80.6	−46.4	±0.5
20	0.96	0.99	0.96	±0.14	−10.9	−77.1	−34.1	±0.5
30	0.98	1.00	0.99	±0.16	−18.6	−85.4	−68.5	±0.6
40	1.00	0.99	0.97	±0.22	−16.8	−83.7	−54.6	±0.8
50	1.06	1.03	1.07	±0.33	−35.5	−102.8	−129.9	±1.2
60	1.3	1.1	1.1	±0.67	−29.5	−98.6	−114.6	±2.4

[a]Manufacturer's specs on the HP 8542A automatic network analyzer.

Table 2. Test data for HP 8761A coaxial switch

Frequency, MHz	Group delay, ns			Transmission coefficient phase, deg		
	4.4°C (40°F)	21.1°C (70°F)	37.8°C (100°F)	4.4°C (40°F)	21.1°C (70°F)	37.8°C (100°F)
Port 1 to C						
2110	0.24	0.23	0.24	−164.4	−164.6	−164.5
2300	0.21	0.21	0.21	−178.9	−179.2	−179.1
8420	0.22	0.22	0.22	66.3	65.3	65.7
Port 2 to C						
2110	0.24	0.24	0.23	−164.4	−164.4	−164.5
2300	0.21	0.21	0.21	−178.9	−179.0	−179.1
8420	0.22	0.22	0.22	66.3	65.8	65.8

Table 3. Test results for Telonic TBP 2114-400-4EF1 bandpass filter

Frequency, MHz	21.1°C (70°F) Insertion loss, dB	Group delay, ns			Transmission coefficient phase, deg		
		4.4°C (40°F)	21.1°C (70°F)	37.8°C (100°F)	4.4°C (40°F)	21.1°C (70°F)	37.8°C (100°F)
1750	10.5	–	1.46	–	–	142.2	–
1800	5.5	–	2.19	–	–	110.6	–
1850	1.6	–	2.71	–	–	63.2	–
1910	0.42	2.32	2.37	2.39	2.2	4.1	5.0
2000	0.47	2.00	2.03	2.00	−65.7	−64.8	−64.2
2100	0.53	2.02	2.03	2.03	−137.8	−137.2	−136.9
2200	0.47	2.22	2.21	2.21	146.2	146.4	146.6
2290	0.80	3.22	3.24	3.23	62.9	62.7	62.9
2350	4.7	–	3.13	–	–	−15.5	–
2400	11.7	–	2.04	–	–	−62.4	–

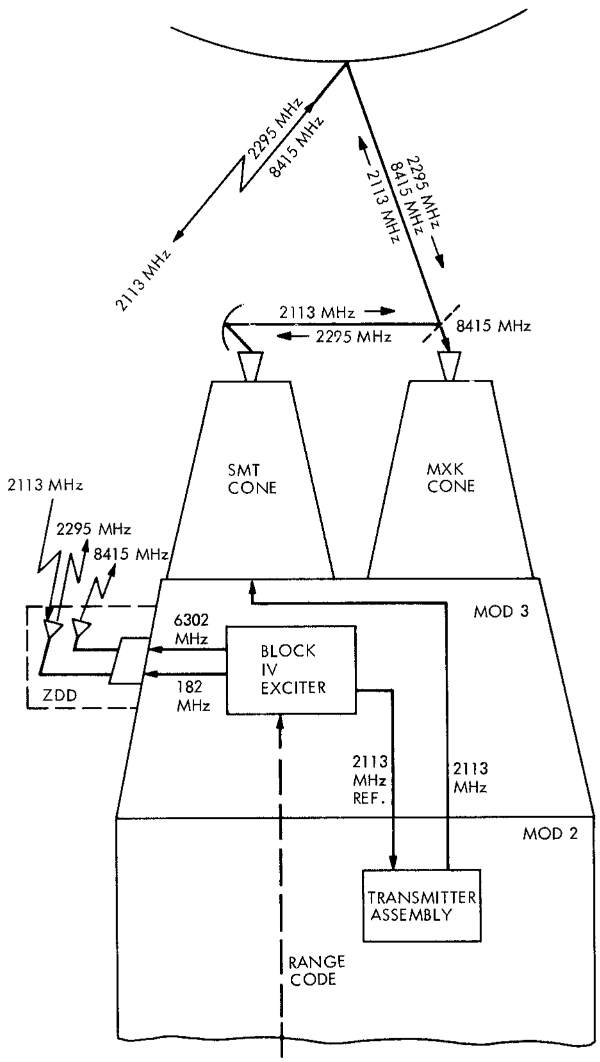

Fig. 1. Simplified block diagram of ZDD calibration system for S/X experiment

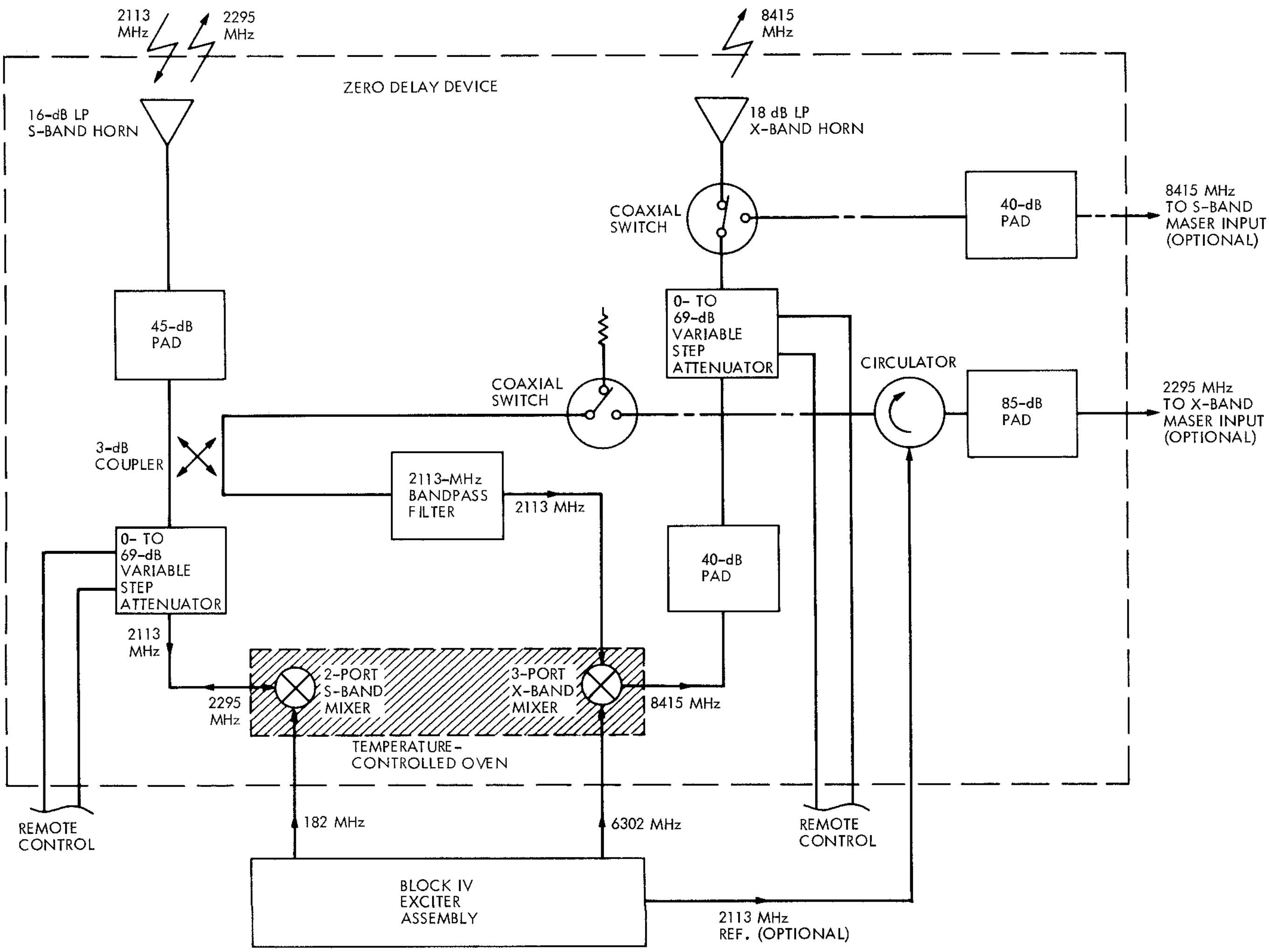

Fig. 2. Preliminary block diagram of ZDD assembly

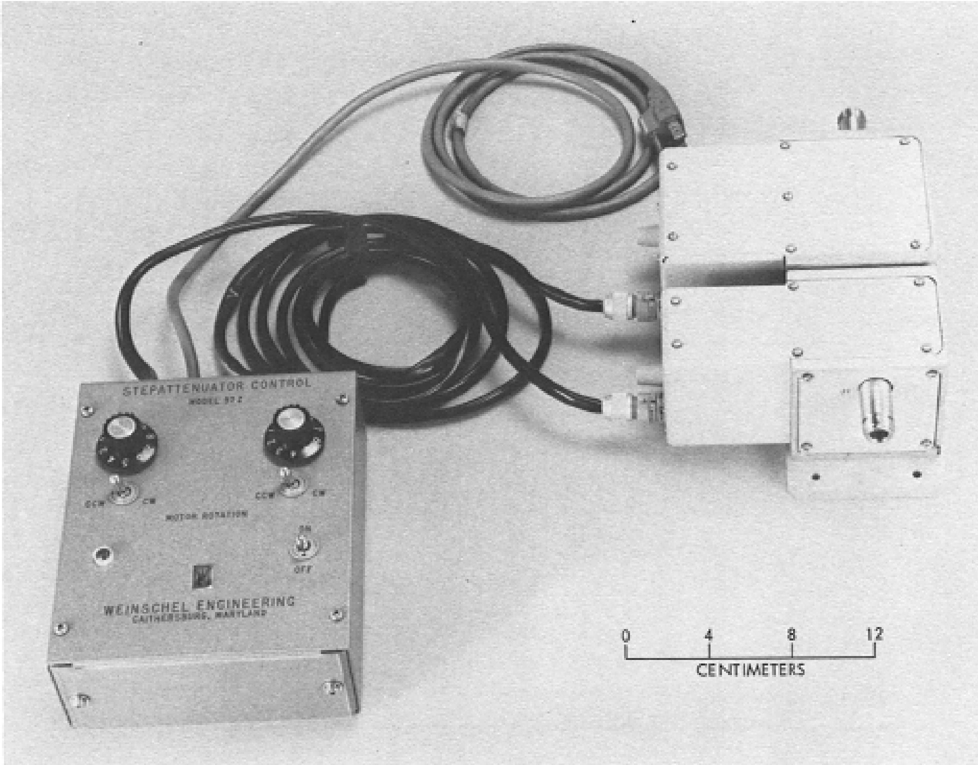

Fig. 3. Remotely controllable coaxial step attenuator, Weinschel Engineering Model AE 97-69-3

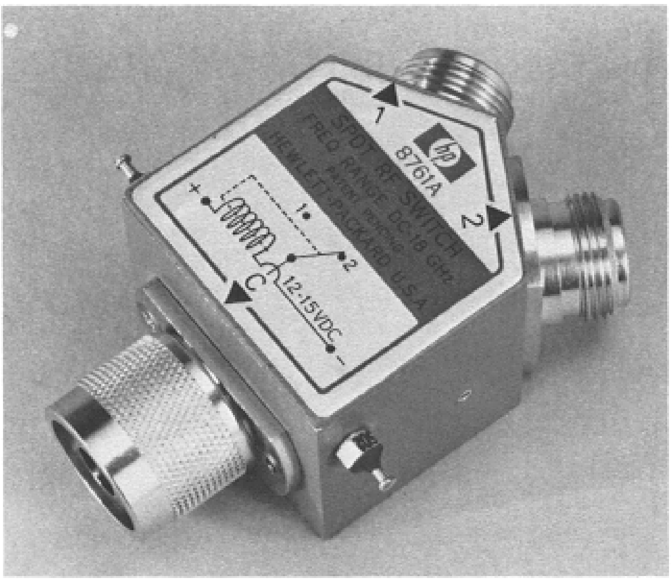

Fig. 4. Remotely controllable coaxial switch, Hewlett-Packard Model HP 8761A

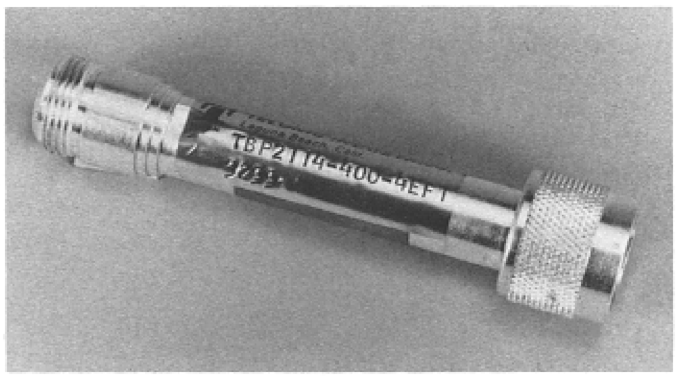

Fig. 5. Coaxial 2113-MHz bandpass filter, Telonic Industries Model TBP 2114-400-4EF1